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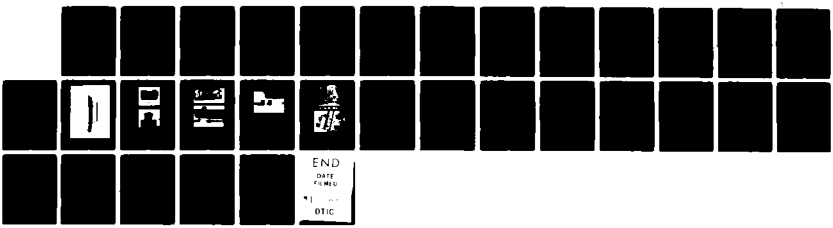

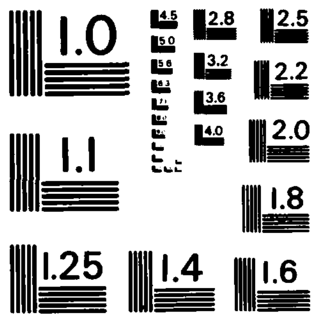


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MANEUVERING CHARACTERISTICS OF THE YP 676 CLASS SEAMANSHIP TRAINING CRAFT AS REPRESENTED BY RADIO-CONTROLLED MODEL 9022

(12)


# DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084


AD-A133722

MANEUVERING CHARACTERISTICS OF THE YP 676 CLASS SEAMANSHIP TRAINING CRAFT AS REPRESENTED BY RADIO-CONTROLLED MODEL 9022

by


Grant A. Rossignol




SHIP PERFORMANCE DEPARTMENT




April 1983

DTNSRDC/SPD-1082-01

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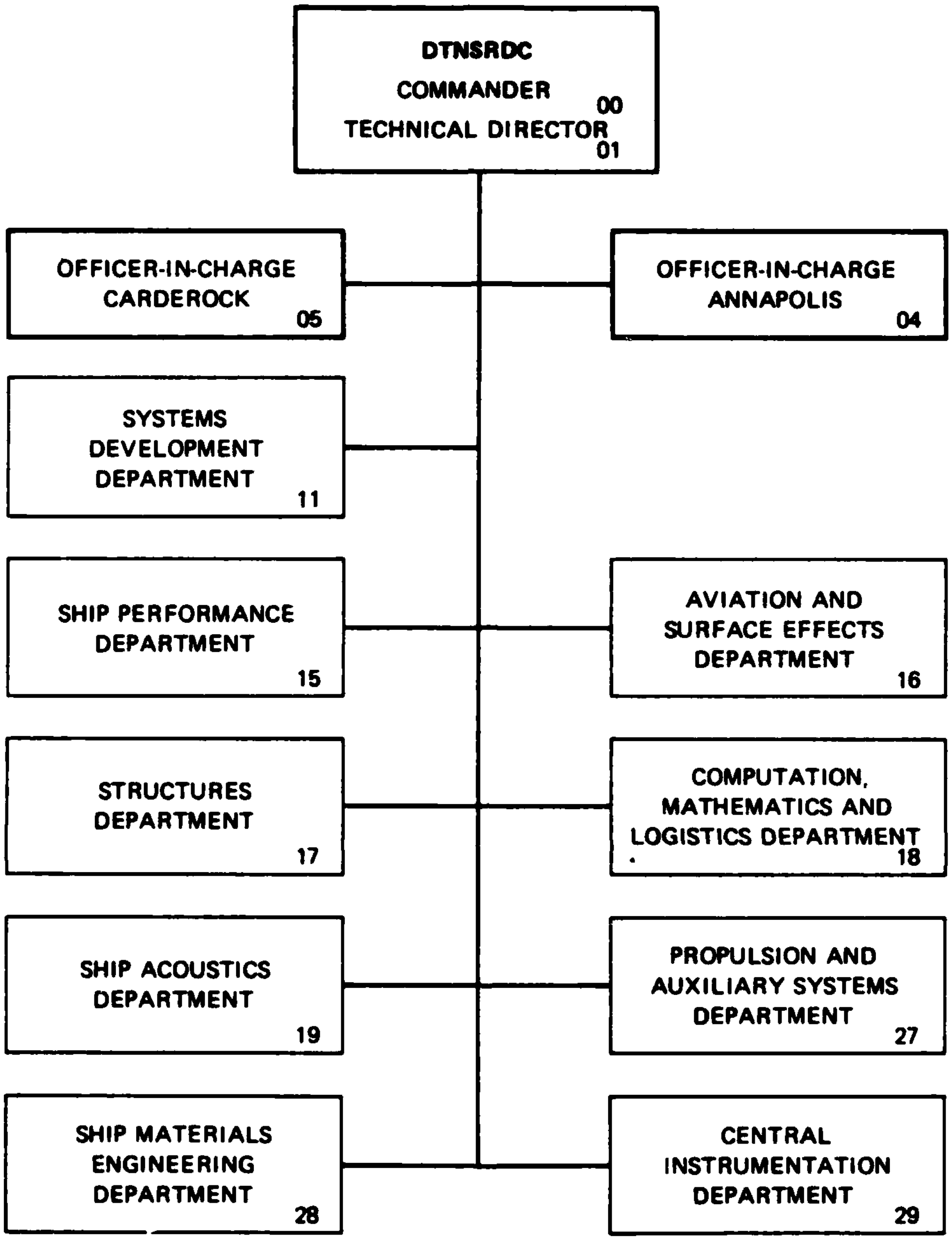

# REPORT DOCUMENTATION PAGE

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the results of maneuvering and roll experiments conducted with radio-controlled Model 9022, representing the YP 676 Class seamanship training craft. The investigation was conducted primarily to determine the optimum rudder size for satisfactory maneuvering performance. The effects of ship speed and displacement on directional stability, rudder controllability, and turning ability were also investigated. The roll ---

decay coefficient and roll response (in beam waves) at zero speed were also determined.

The results indicate that the YP 676 will exhibit much better than usual ahead or astern maneuvering performance for all of the conditions investigated. In particular, the YP 676 turning performance will exceed that of the YP 660 Class (which is being replaced by the YP 676). In view of these results and various practical considerations, the smaller set of rudders are recommended for inclusion in the final YP 676 design.

## TABLE OF CONTENTS



## LIST OF FIGURES

Page



LIST OF TABLES

## NOTATION

| | |
|---|---|
| $B$ | Maximum beam |
| $GM_T$ | Transverse metacentric height |
| LCG | Longitudinal center of gravity |
| LOA | Length overall |
| $L_{pp}$ | Length between perpendiculars |
| $N$ | Roll decay coefficient |
| $T$ | Draft |
| $T_\phi$ | Natural roll period |
| $V$ | Ship speed |
| $\Delta$ | Displacement (weight) |
| $\delta_r$ | Rudder angle |
| $\phi_a$ | Mean roll amplitude |
| $\lambda$ | Wave length |
| $\psi$ | Yaw angle (change of heading) |
| $\dot{\psi}$ | Yaw rate (rate of change of heading |

## ABSTRACT

This report presents the results of maneuvering and roll experiments conducted with radio-controlled Model 9022, representing the YP 676 Class seamanship training craft. The investigation was conducted primarily to determine the optimum rudder size for satisfactory maneuvering performance. The effects of ship speed and displacement on directional stability, rudder controllability, and turning ability were also investigated. The roll decay coefficient and roll response (in beam waves) at zero speed were also determined.

The results indicate that the YP 676 will exhibit much better than usual ahead or astern maneuvering performance for all of the conditions investigated. In particular, the YP 676 turning performance will exceed that of the YP 660 Class (which is being replaced by the YP 676). In view of these results and various practical considerations, the smaller set of rudders are recommended for inclusion in the final YP 676 design.


## ADMINISTRATIVE INFORMATION


This work was authorized by Naval Sea Combat Systems Engineering Station, Norfolk Work Request 1-1067. The work was performed under David Taylor Naval Ship Research and Development Center Work Unit Number 1561-864.


## INTRODUCTION

The Naval Sea Combat Systems Engineering Station, Norfolk (NAVSEACOMBATSYSENGSTA) Norfolk requested the David Taylor Naval Ship Research and Development Center (DTNSRDC) to conduct maneuvering and roll experiments in support of the YP 676 design. The YP 676 class represents an improved seamanship and navigation training craft, replacing the the YP 660 class, to be used at the United States Naval Academy.

Experiments were conducted in the Saunders Maneuvering and Seakeeping (MASK) Facility with a radio-controlled, free-running model using two rudder sizes and two displacements. Spiral, zigzag, and turning maneuvers were conducted for both rudder sizes at the full load displacement; while spiral, ahead zigzag, and astern zigzag maneuvers were conducted for the smaller rudder size at the light draft displacement. Regular wave roll and calm water roll decay experiments were also conducted at zero speed for the smaller rudder size at the full load displacement. Unfortunately, the experiment and data collection setups precluded proper conduct of regular wave experiments. The roll transfer function obtained for beam waves at zero speed was below satisfactory quality and is not presented in this report.

## DESCRIPTION OF PROTOTYPE AND MODEL

The principal characteristics of the ship and model are given in Table 1. The YP 676 designs, as represented by Model 9022, has a length between perpendiculars of 101.67 feet (30.99 meters) and a displacement of 161.28 long tons (163.87 tonnes) at the full load displacement. The displacement will be 131.39 long tons (133.50 tonnes) when the ship operates at the light draft displacement. The ship is steered by twin, spade rudders and propelled by twin, outward turning (ahead) propellers. The ship is also appended with a combination box keel and centerline skeg. Roll damping is provided by bilge keels. The model, as shown in Figures 1 through 3, is a 1:6 scale version of the ship.

Center propellers 4344 and 4345 representing a diameter of 4.33 feet (1.32 meters) and having three blades were used for these experiments. The larger set of rudders (A) has an area of 12.85 square feet (1.19 square meters) each; while the area of the smaller set (B) is 10.56 square feet (0.98 square meters). Figure 4 shows details of the rudder size comparison and stern (rudders and propulsion) arrangements.

The model was equipped with a radio-controlled system. This system consists of three basic components: receiving/transmitting equipment on shore, receiving/transmitting equipment in the model, and steering/propulsion control units in the model. Figure 5 shows some of the radio-controlled equipment in the model. A complete description of the radio-controlled equipment is given in Reference 1.*

## EXPERIMENT PROCEDURE

The experiments were conducted with the model ballasted to the particulars given in Table 1. Time histories of yaw rate, yaw angle, roll, and rudder angle were measured by a rate gyro, heading gyro, roll gyro, and rudder servo, respectively. The signals from these transducers were recorded on strip chart recorders. The x-y coordinates of the model path was obtained from photographic plates (using overhead cameras) during the turning maneuvers. The equations/formulas used for the roll decay data are given in the Appendix.

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*A complete listing of references is given on page 5.

The spiral maneuvers were conducted for the full load ballast condition using both the large rudders, (A), and the small rudders, (B), at ship speeds of 5 and 7 knots. An additional spiral maneuver was conducted for the light draft ballast condition using rudders (B) at a ship speed of 7 knots.

Zigzag maneuvers were conducted for essentially the same conditions used for the spiral maneuvers. For the rudder comparisons at the full load ballast condition, 10-10 (execute rudder angle-change of heading at executes) zigzag maneuvers were performed at ship speeds of 5 and 7 knots; while 20-20 zigzag maneuvers were performed for 7 knots only. Additional zigzag maneuvers were performed astern for the light draft ballast condition using rudders (B) at a ship speed of 5 knots. The full-scale rudder rate used was 11.4 degrees per second (the average rate measured from right 30 degrees to left 30 degrees in a right 35 degree to left 35 degree swing).

Turning maneuvers were conducted for only the full load displacement using both sets of rudders. Turns were made at ship speeds of 5, 7, and 11 knots using execute rudder angles of left and right 20 and 30 degrees.

Roll decay experiments were conducted at zero speed. The set of small rudders and light draft displacement were used for these experiments.

The exact model speed control settings required to simulate particular ship speeds were determined by conducting ahead/astern coursekeeping maneuvers. While at a steady speed, the model was powered over a course of known distance and timed to determine the true speed. These maneuvers were conducted over a speed range of 2 to 11 knots ahead (full load) and up to 5 knots astern (light draft). Complete descriptions of typical spiral, zigzag, and turning maneuvers are given in Reference 2. Table 2 summarizes the maneuvers conducted.

## PRESENTATION OF RESULTS

The results of the coursekeeping/speed calibration maneuvers are presented in Figure 6. Figures 7 through 11 present the results of the spiral maneuvers. The effects on directional stability of rudder size, ship speed, and ballast condition can be seen. The data shows that the ship will have excellent directional stability in all cases. In addition, the zigzag data in Table 3 shows that the ship will have unusually good rudder controllability

(as evidenced by the small overshoot angles) regardless of which set of rudders is used.

Figure 12 presents tactical diameters obtained from turning maneuvers for both sets of rudders at the full load displacement. The data shows that the YP 676 will turn tighter than most ships regardless of which set of rudders is used. Comparisons between the YP 676 model results and YP 660 full-scale trial results are shown in Figure 13. Even with the smaller set of rudders, the YP 676 clearly out performs the existing ship.

The primary objective of this experiment was to determine the optimum rudder size for satisfactory YP 676 maneuvering performance. Based upon observations made of the model's performance during the experiment and the results presented here, the set of small rudders, (B), are recommended for the YP 676 design. The directional stability, rudder controllability, and turning ability of the YP 676 when appended with rudders (B) will be excellent and probably exceed those of most existing ships (including the YP 660). Smaller rudders also have the obvious advantages of reduced resistance, steering gear size, and construction cost. Observations made of astern stability on course (coursekeeping) and rudder controllability also indicate that either set of rudders will provide excellent astern maneuverability.

Figure 14 presents the results of the roll decay experiment.

## CONCLUSIONS AND RECOMMENDATIONS

Based upon the results of the various maneuvers, the following conclusions are drawn:

a. The ship will have a high degree of directional stability for either set of rudders and both ballast conditions at ship speeds of 5 knots and greater.

b. The ship will have unusually good rudder controllability for either set of rudders at the full load ballast condition.

c. The ship will turn tighter than the YP 660 class regardless of which set of rudders is used. The ship's turning performance is also considered excellent.

d. The astern maneuverability will be excellent for either set of rudders.

As a result of this experiment, the recommendation is made that the set of small rudders, (B), be used for the final YP 676 design.

## REFERENCES

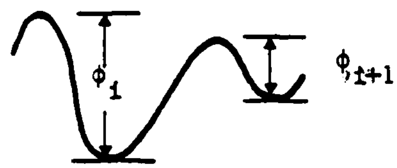
1. Motter, L.E. and Huminik, D. "Free Running Radio Controlled Surface Ship Model Experiments. Part I: Multiplex and Telemetry Equipment," DTNSRDC Report, DTNSRDC/SPD-1017-01 (Nov 1981).

2. Comstock, J. P. (Editor), "Principals of Naval Architecture," published by the Society of Naval Architects and Marine Engineers, 1967, pp. 463-574.

## APPENDIX - FORMULAS AND EQUATIONS

**Roll decay coefficient.**

The roll time history obtained from a typical roll decay experiment looks as follows:




The roll decay coefficient, N, is calculated by

$$N = \frac{1}{2\pi} \ln \frac{\phi_i}{\phi_{i+1}}$$

and the mean roll amplitude is calculated by

$$\phi_a = \frac{\phi_i + \phi_{i+1}}{4} .$$

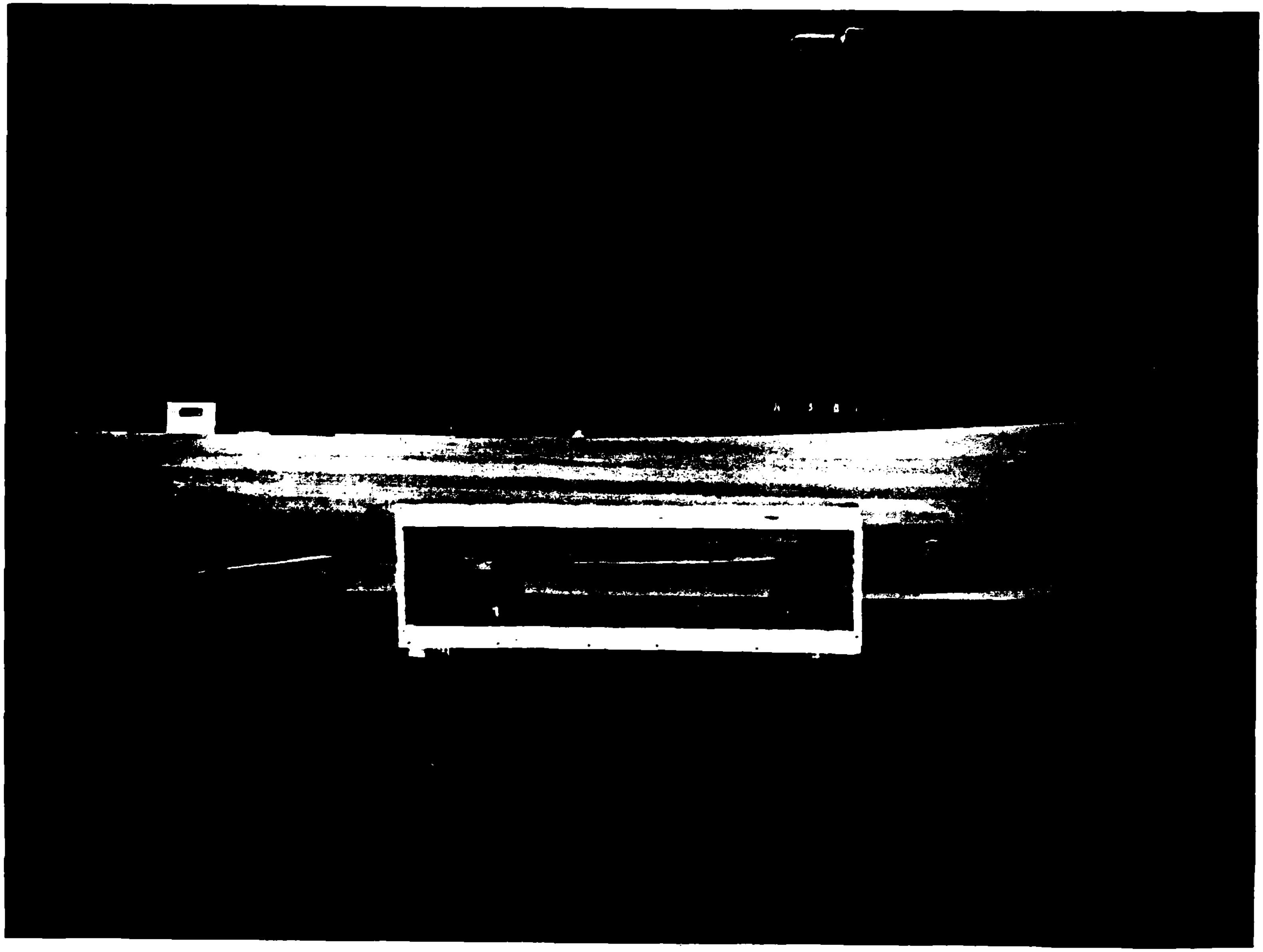
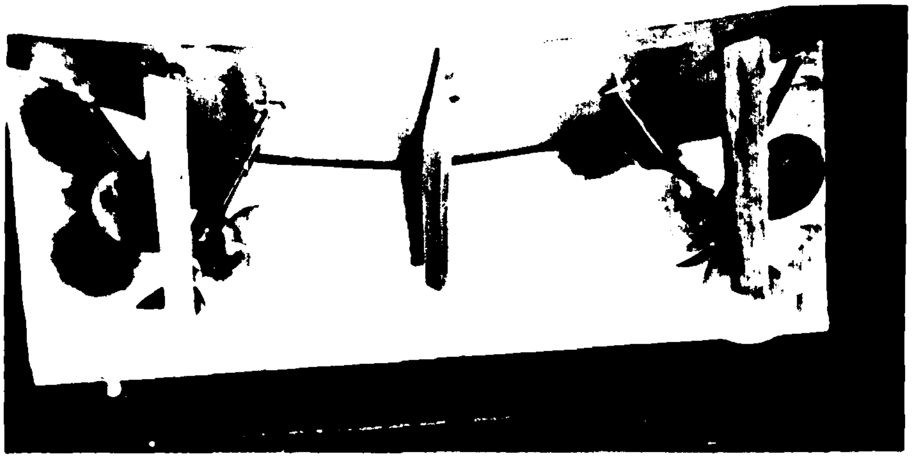


Figure 1 - Photograph Showing Starboard Profile View of Model 9022


Figure 2 - Photographs Showing Transverse Bow and Stern Views of Model 9022



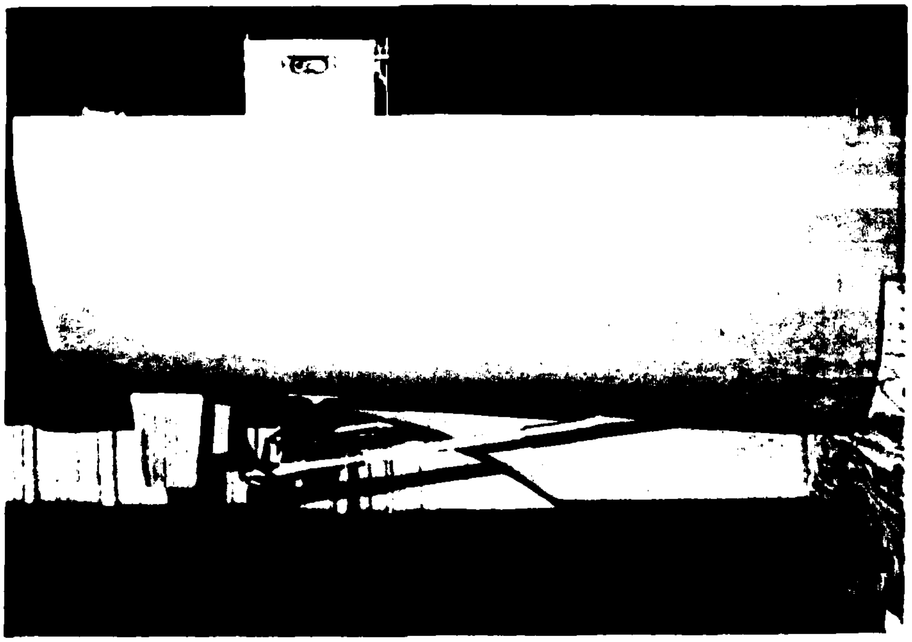


Figure 3 - Photographs Showing Stern Details of Model 9022

Figure 4 - Photograph Showing Comparative Sizes
of Rudders (A) and (B)

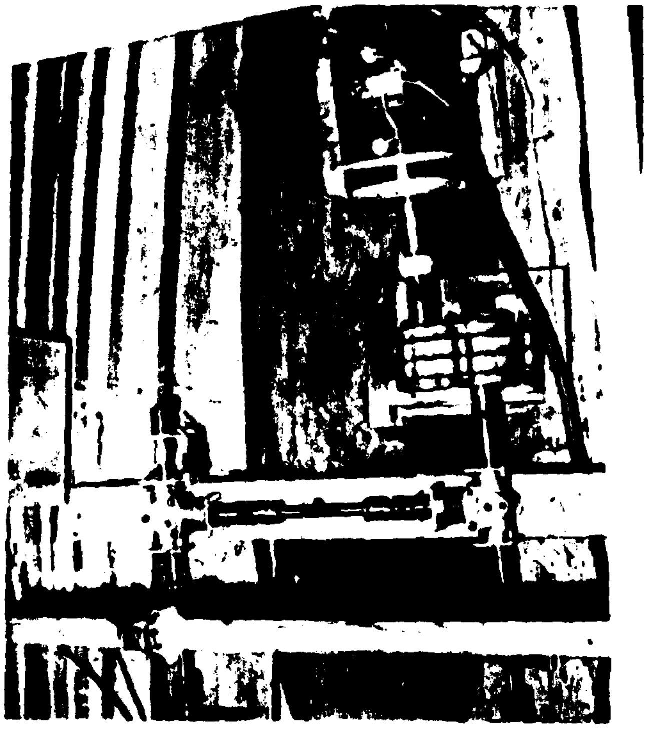


Figure 5 - Photographs Showing Details of the Radio-Control Equipment Installed in Model 9022

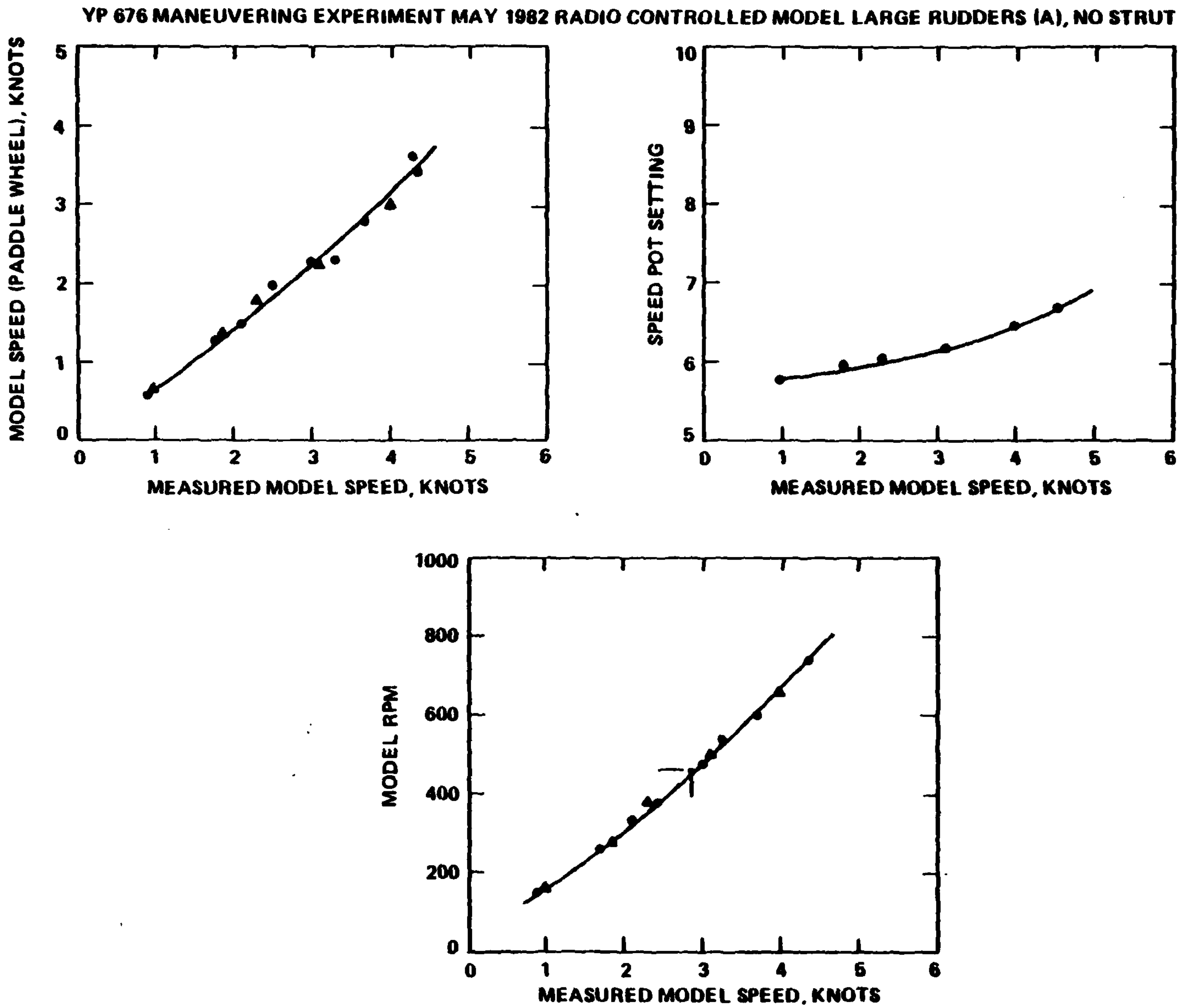



Figure 6 - Model RPM, Speed Pot Setting, and Paddle Wheel Speed versus Measured Model Speed from Coursekeeping/Speed Calibration Maneuvers Conducted with the YP 676 with the large Rudders (A); Full Load Displacement

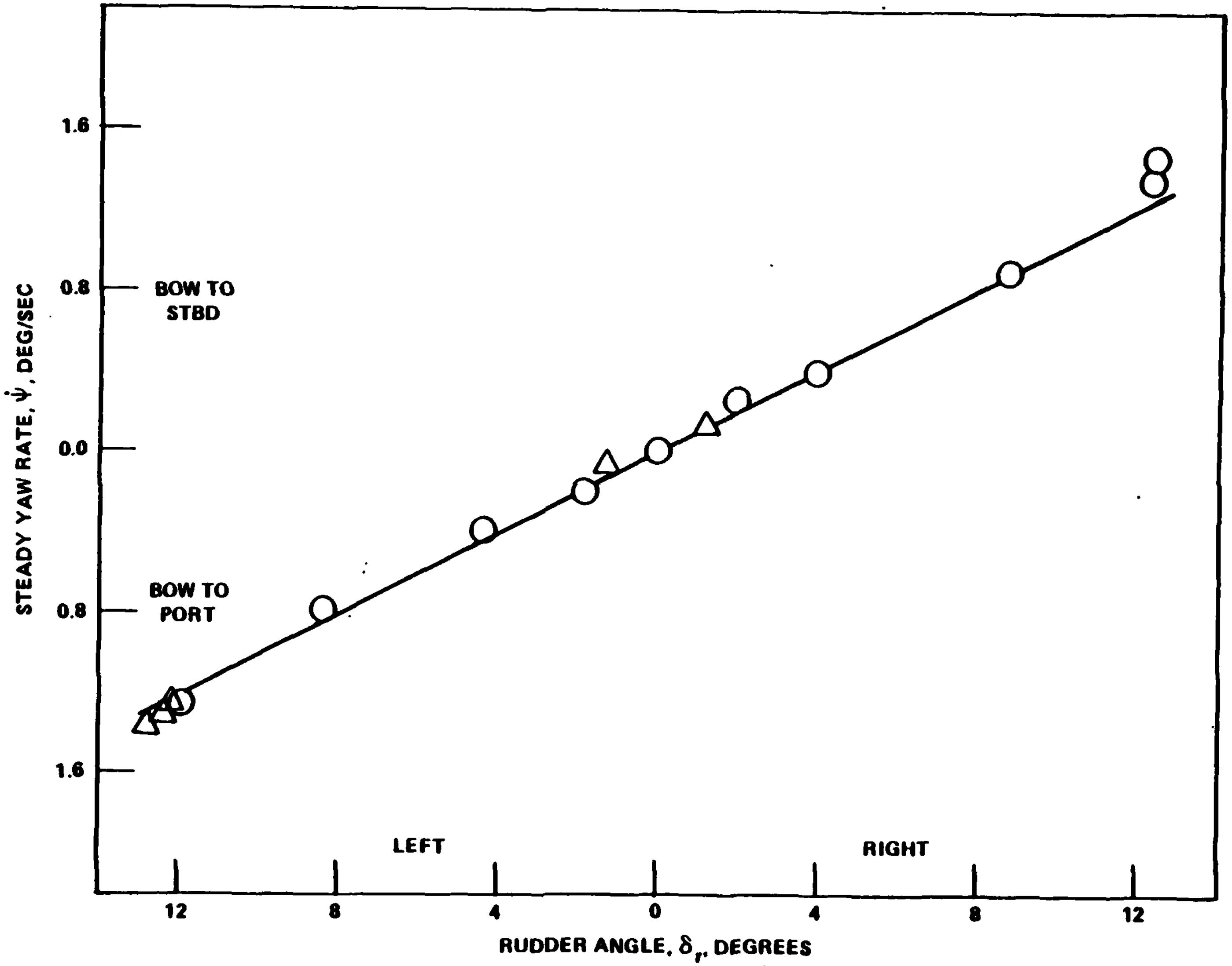



Figure 7 - Steady Yaw Rate versus Rudder Angle from Spiral Maneuvers Conducted With the YP 676 Appended with the Large Rudders (A) at a Ship Speed of 5 Knots; Full Load Displacement

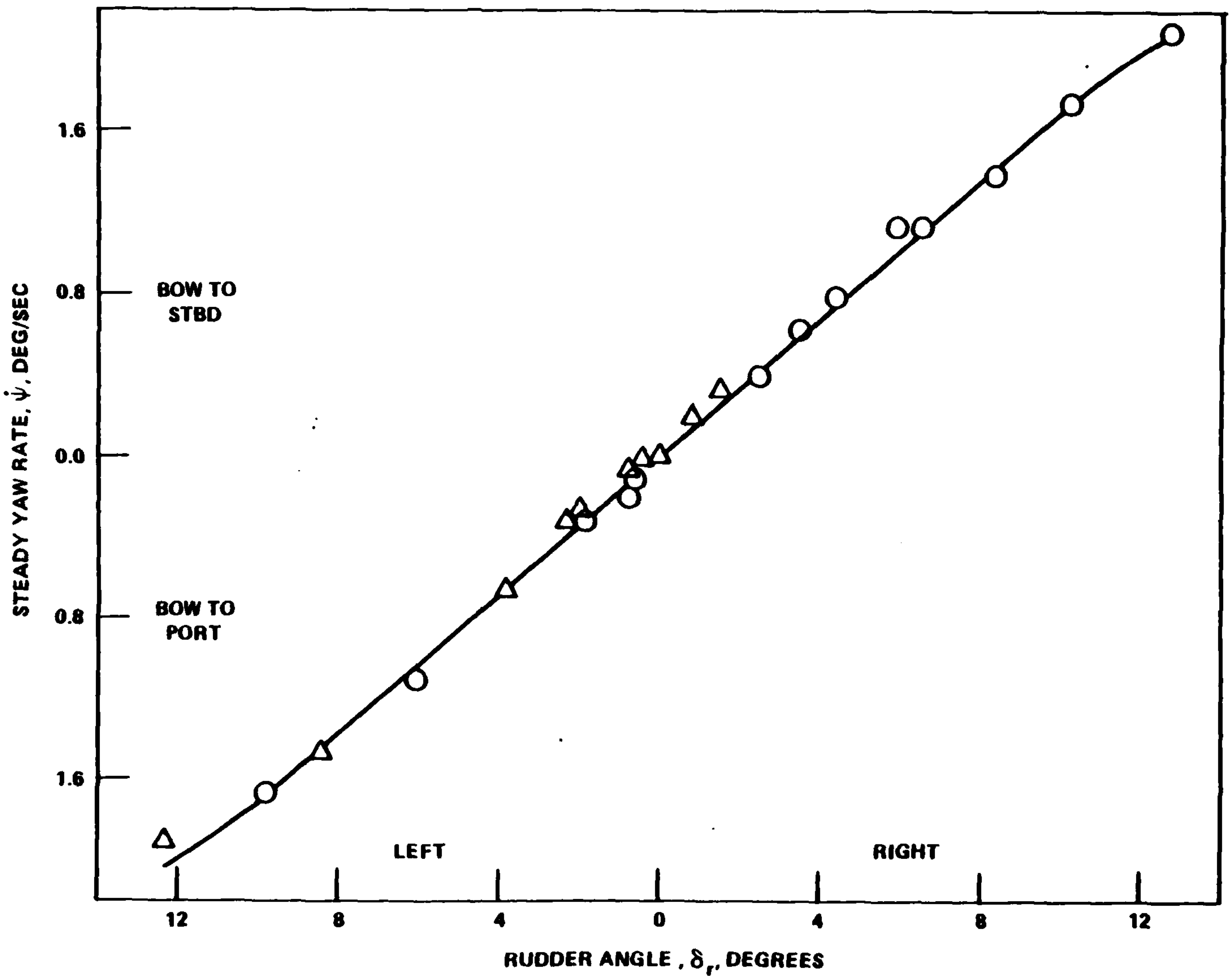



Figure 8 - Steady Yaw Rate versus Rudder Angle from Spiral Maneuvers Conducted With the YP 676 Appended with the Large Rudders (A) at a Ship Speed of 7 Knots; Full Load Displacement

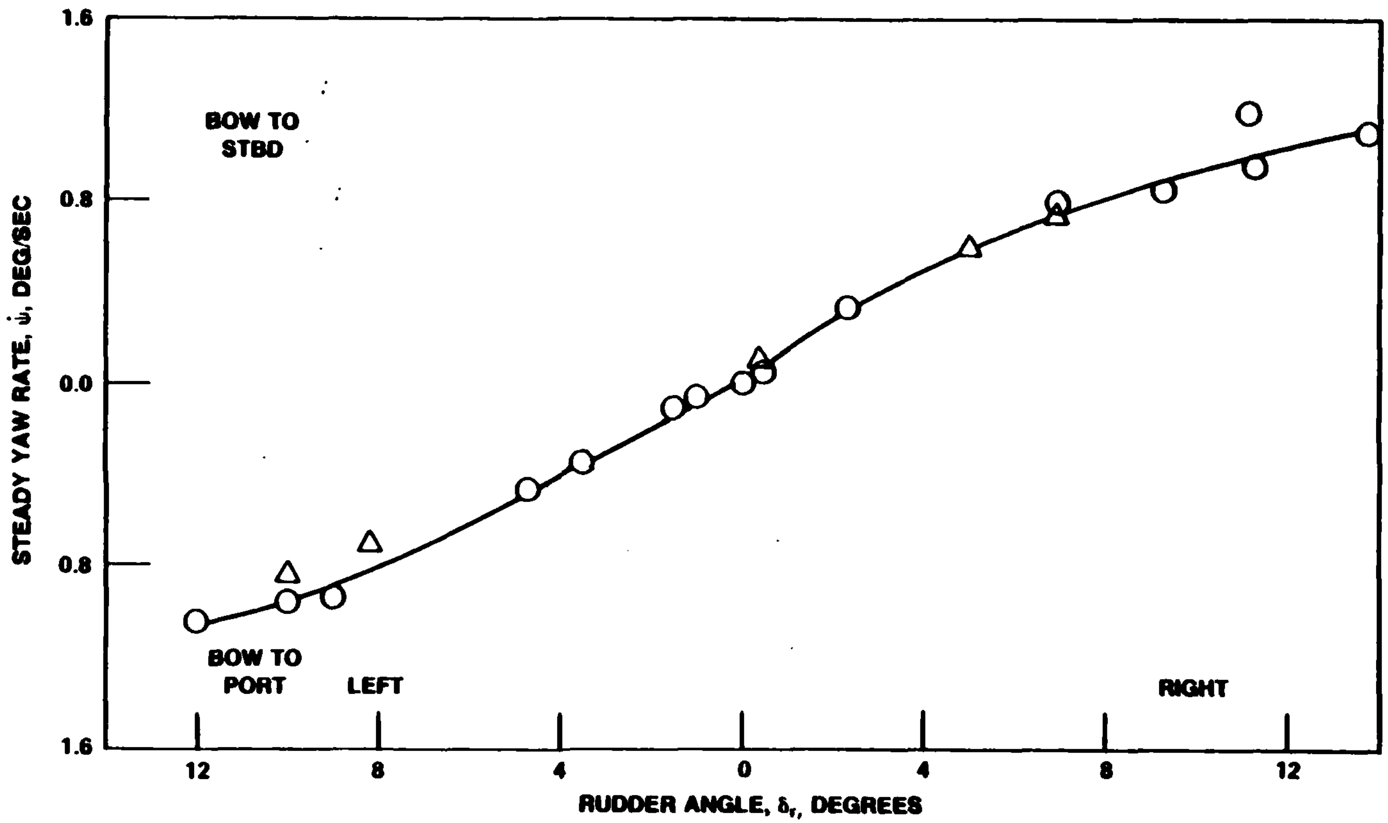



Figure 9 – Steady Yaw Rate versus Rudder Angle from Spiral Maneuvers Conducted with the YP 676 Appended with the Small Rudders (B) at a Ship Speed of .5 Knots; Full Load Displacement

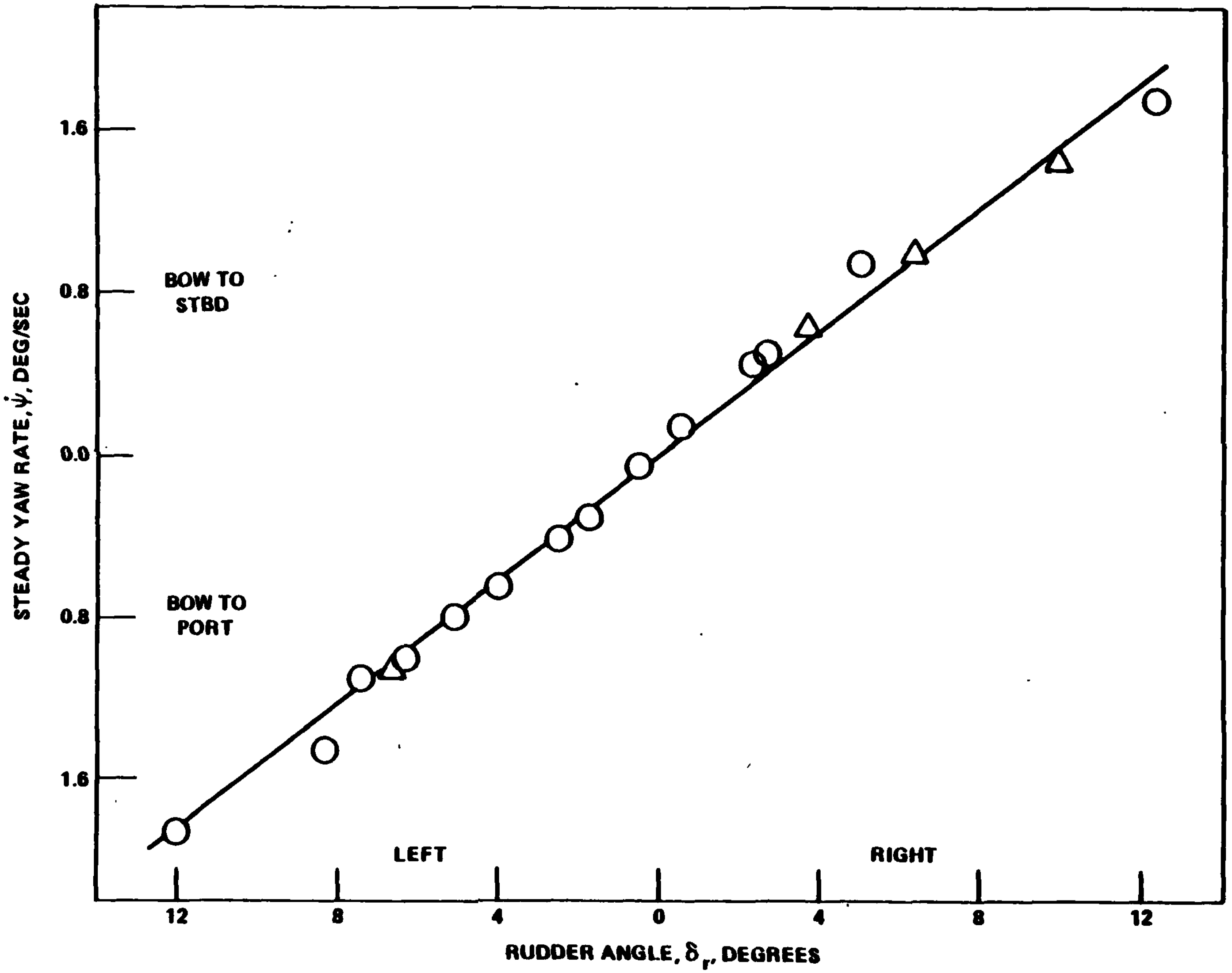



Figure 10 - Steady Yaw Rate versus Rudder Angle from Spiral Maneuvers Conducted With the YP 676 Appended with the Small Rudders (B) at a Ship Speed of 7 Knots; Full Load Displacement

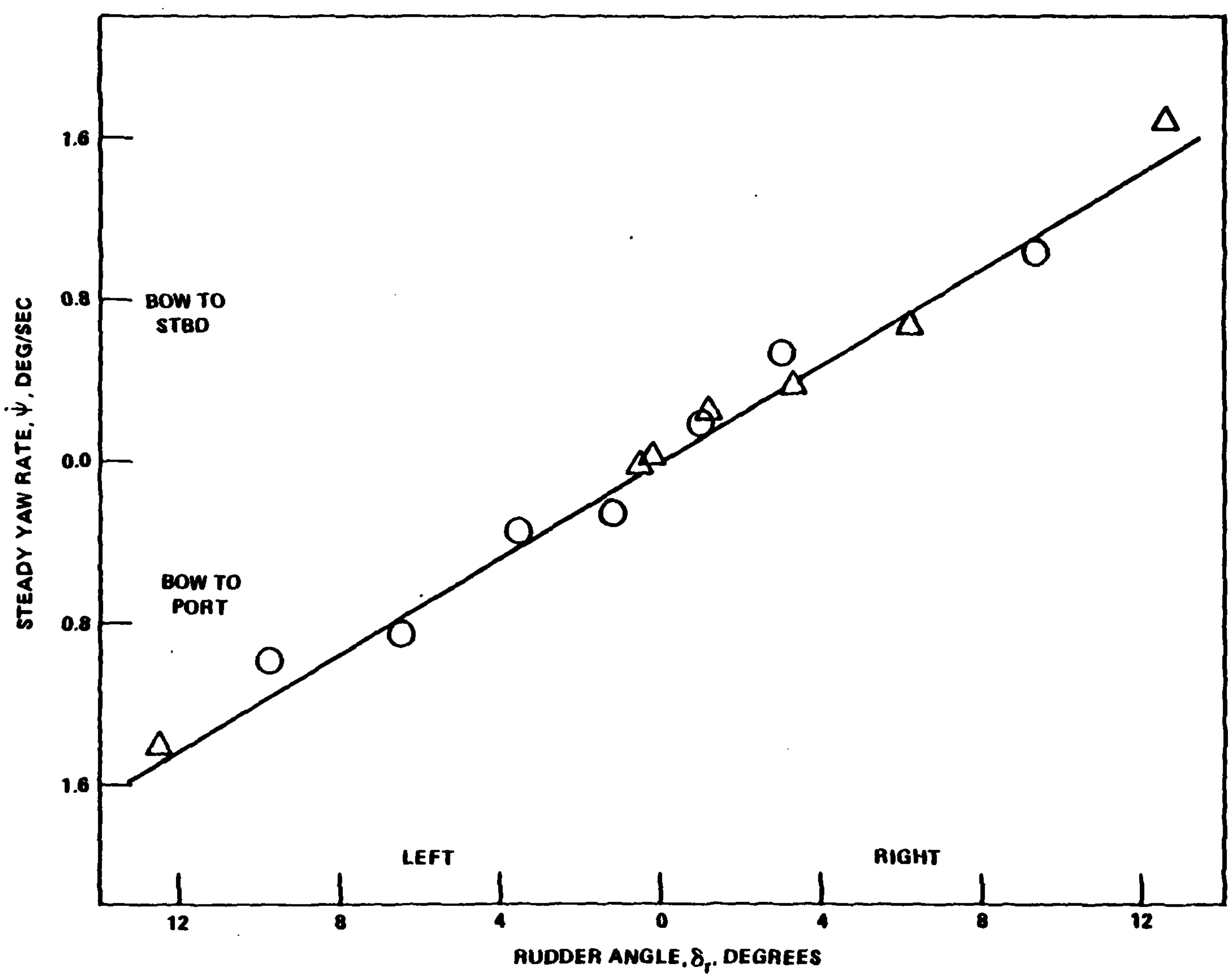



Figure 11 - Steady Yaw Rate versus Rudder Angle from Spiral Maneuvers Conducted With the YP 676 Appended with the Small Rudders (B) at a Ship Speed of 7 Knots; Light Draft Displacement

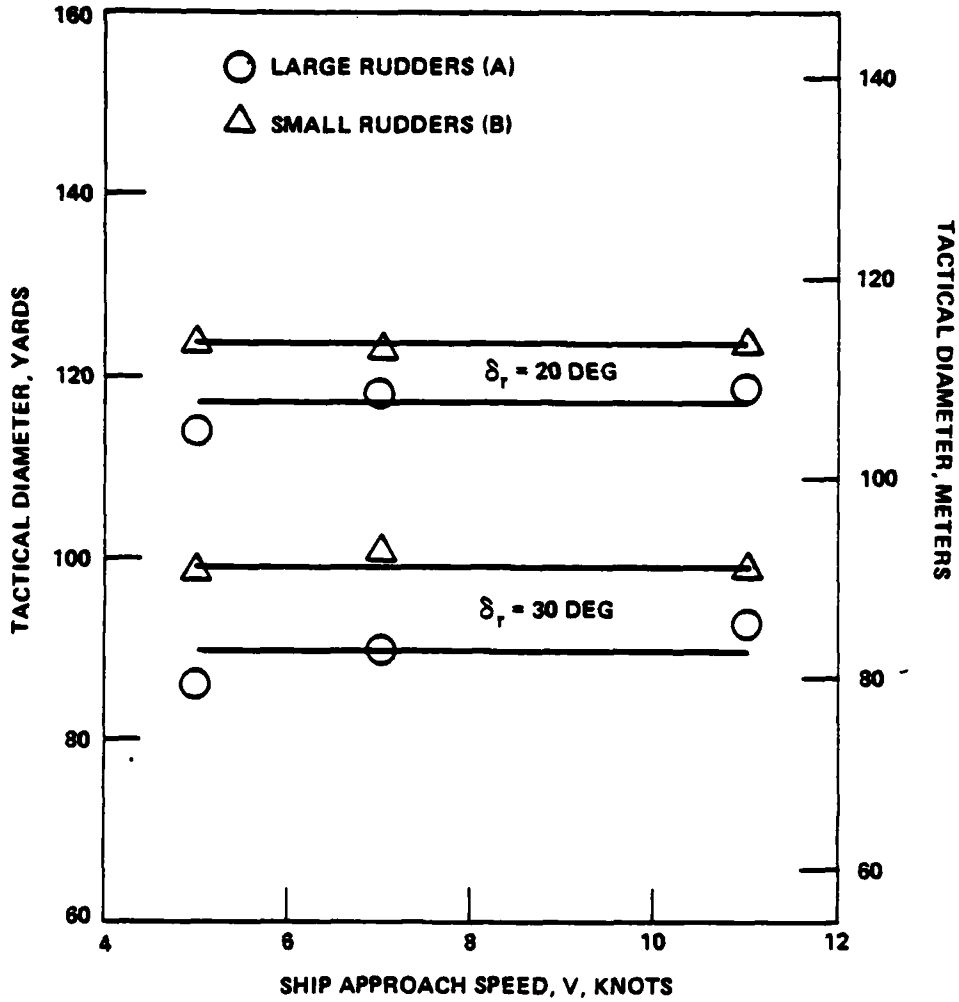



Figure 12 - Tactical Diameter versus Ship Approach Speed from Turning Maneuvers Conducted with the YP 676 for Rudders A and B; Full Load Displacement

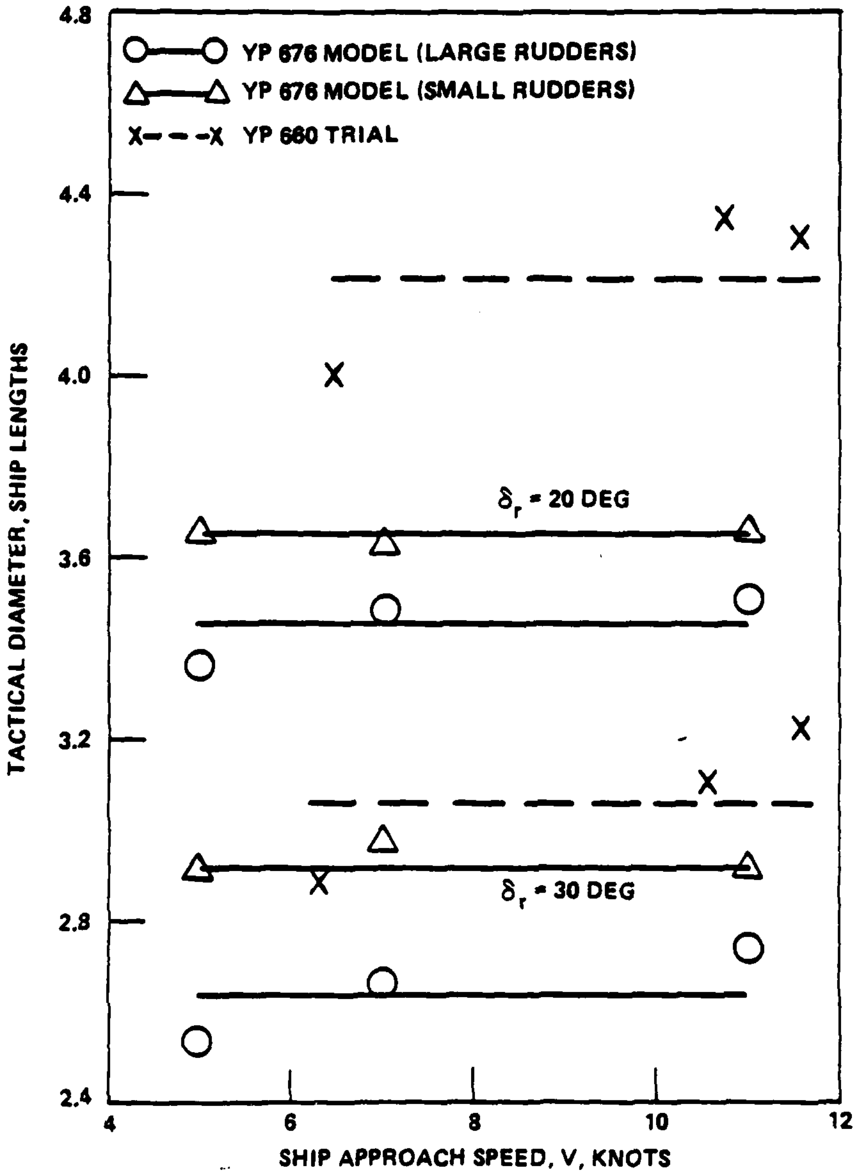



Figure 13 - Tactical Diameter versus Ship Approach Speed Comparing Results from Turning Maneuvers Conducted with the YP 676 (Model) and the YP 660 (Trial)

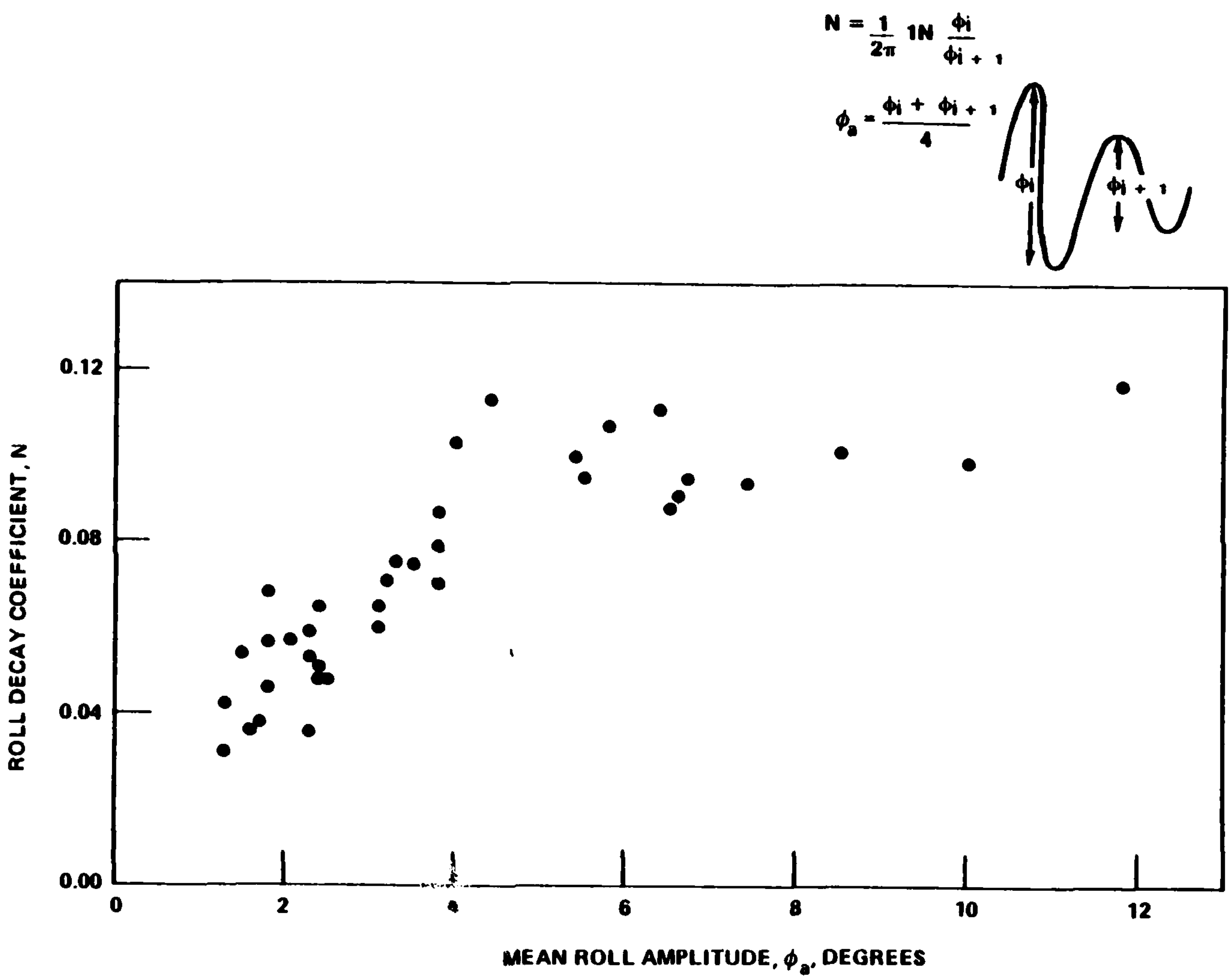



Figure 14 - Roll Decay Coefficient versus Mean Roll Amplitude for the YP 676 at Zero Speed; Small Rudders (B) and Full Load Displacement

## TABLE 1 - YP 676 PARTICULARS

SHIP-YP 676
DRAWING NO.-NAVSEA 5103418 25 FEB 82
MODEL NO.-9022
MODEL PROPELLER NO.-4344, 4345
LINEAR RATIO-6.0

| | Light Draft | | | | Full Load | | | |
|---|---|---|---|---|---|---|---|---|
| | Ship | | Model | | Ship | | Model | |
| LOA, ft (m) | 108.00 | (32.92) | 18.00 | (5.49) | 108.00 | (32.92) | 18.00 | (5.49) |
| $L_{pp}$, ft (m) | 101.67 | (30.99) | 16.95 | (5.17) | 101.67 | (30.99) | 16.95 | (5.17) |
| B, ft (m) | 20.79 | (6.34) | 3.47 | (1.06) | 21.21 | (6.46) | 3.54 | (1.08) |
| T(FP), ft (m) | 4.15 | (1.26) | 0.69 | (0.21) | 4.75 | (1.45) | 0.79 | (0.24) |
| T(AP), ft (m) | 6.15 | (1.87) | 1.03 | (0.31) | 6.75 | (2.06) | 1.13 | (0.34) |
| T(mean), ft (m) | 5.15 | (1.57) | 0.86 | (0.26) | 5.80 | (1.77) | 0.97 | (0.30) |
| $T_\phi$ (0 knots), sec | 4.90 | | 2.00 | | 4.90 | | 2.00 | |
| Trim, ft (m) by the stern | 2.00 | (0.61) | 0.33 | (0.10) | 2.00 | (0.61) | 0.33 | (0.10) |
| $\Delta$, tons S.W. (tonnes), lb F.W. (kg) | 131.39 | (133.50) | 1328.00 | (602.38) | 161.28 | (163.87) | 1630.00 | (739.37) |
| $GM_T$ (corrected), ft (m) | 5.02 | (1.53) | 0.84 | (0.26) | 3.76 | (1.15) | 0.63 | (0.19) |
| LCG, ft (m) aft | 3.42 | (1.04) | 0.57 | (0.17) | 4.13 | (1.26) | 0.69 | (0.21) |
| Number of propellers | 2 | | 2 | | 2 | | 2 | |
| Number of blades | 3 | | 3 | | 3 | | 3 | |
| Direction of propeller rotation | Outward | | Outward | | Outward | | Outward | |
| Propeller diameter, ft (m) | 4.33 | (1.32) | 0.72 | (0.22) | 4.33 | (1.32) | 0.72 | (0.22) |
| Propeller pitch, ft (m) | 4.55 | (1.39) | 0.76 | (0.23) | 4.55 | (1.39) | 0.76 | (0.23) |
| Number of rudders | 2 | | 2 | | 2 | | 2 | |
| Rudder type | Spade | | Spade | | Spade | | Spade | |
| Rudder area (A), $ft^2$ ($m^2$) | 12.85 | (1.19) | 0.36 | (0.033) | 12.85 | (1.19) | 0.36 | (0.033) |
| Rudder area (B), $ft^2$ ($m^2$) | 10.56 | (0.98) | 0.29 | (0.027) | 10.56 | (0.98) | 0.29 | (0.027) |
| Rudder rate, deg/sec (1200 RPM) | 11.40 | | 27.92 | | 11.40 | | 27.92 | |

TABLE 2 - YP 676 MANEUVERING EXPERIMENT
SUMMARY OF CONDITIONS

| Displacement | Rudders | Type of Maneuver | Ship Speed knots | Rudder Angle degrees |
|---|---|---|---|---|
| Full load | Large (A) | Coursekeeping/speed calibration | 2-11 | -- |
| | | Spiral | 5 | -- |
| | | | 7 | -- |
| | | 10-10 zigzag | 5 | L/R 10 |
| | | | 7 | L/R 10 |
| | | 20-20 zigzag | 7 | L/R 20 |
| | | Turning | 5 | |
| | | | | L 20 |
| | | | | L 30 |
| | | | | R 20 |
| | | | | R 30 |
| | | | 7 | L 20 |
| | | | | L 30 |
| | | | | R 20 |
| | | | | R 30 |
| | | | 11 | L 20 |
| | | | | L 30 |
| | | | | R 20 |
| | | | | R 30 |
| | Small (B) | Spiral | 5 | -- |
| | | | 7 | -- |
| | | 10-10 zigzag | 5 | L/R 10 |
| | | | 7 | L/R 10 |
| | | 20-20 zigzag | 7 | L/R 20 |
| | | Turning | 5 | L 20 |
| | | | | L 30 |
| | | | | R 20 |
| | | | | R 30 |

TABLE 2 (Continued)

| Displacement | Rudders | Type of Maneuver | Ship Speed knots | Rudder Angle degrees |
|---|---|---|---|---|
| | | | 7 | L 20 |
| | | | | L 30 |
| | | | | R 20 |
| | | | | R 30 |
| | | | 11 | L 20 |
| | | | | L 30 |
| | | | | R 20 |
| | | | | R 30 |
| | | Roll decay | 0 | -- |
| | | Roll seakeeping | 0 | -- |
| Light draft | Small (B) | Spiral | 7 | -- |
| | | 20-20 zigzag | 7 | L/R 20 |
| | | 20-20 astern zigzag | 5 | L/R 20 |

TABLE 3 - SUMMARY OF DATA OBTAINED FROM ZIGZAG MANEUVERS CONDUCTED WITH THE YP 676

| | Large Rudders (A) | | | Small Rudders (B) | | | | |
|---|---|---|---|---|---|---|---|---|
| | Full Load | | | Full Load | | | Light Draft | |
| | Ahead | | | Ahead | | | Ahead | Astern |
| Ship Approach Speed, knots | 5 | 7 | 7 | 5 | 7 | 7 | 7 | 5 |
| Execute Rudder Angle, degrees | 10 | 10 | 20 | 10 | 10 | 20 | 20 | 20 |
| Change of Heading at Executes, degrees | 10 | 10 | 20 | 10 | 10 | 20 | 20 | 20 |
| Time from 1st to 2nd Executes, seconds | 14 | 12 | 13 | 21 | 15 | 15 | 17 | 43 |
| 3rd | 49 | 38 | 41 | 62 | 44 | 45 | 53 | 104 |
| 4th | 81 | 64 | 71 | 105 | 75 | 76 | 91 | -- |
| Travel from 1st to 2nd Executes, shiplengths | 1.16 | 1.39 | 1.51 | 1.74 | 1.74 | 1.74 | 1.97 | 3.57 |
| 3rd | 4.07 | 4.41 | 4.76 | 5.15 | 5.10 | 5.22 | 6.15 | 8.63 |
| 4th | 6.72 | 7.42 | 8.24 | 8.72 | 8.70 | 8.82 | 10.56 | -- |
| Overshoot after 2nd Execute, degrees | 3.80 | 3.50 | 9.60 | 3.30 | 5.00 | 10.90 | 7.90 | 2.00 |
| 3rd | 4.10 | 5.40 | 11.20 | 4.00 | 6.20 | 12.00 | 9.80 | 7.30 |
| 4th | 4.40 | 5.80 | 10.90 | 4.40 | 5.90 | 11.40 | 9.70 | -- |
| Reach, seconds | 40 | 32 | 35 | 52 | 37 | 38 | 45 | 94 |
| shiplengths | 3.32 | 3.71 | 4.06 | 4.32 | 4.29 | 4.41 | 5.22 | 7.80 |
| Period, seconds | 67 | 51 | 58 | 84 | 60 | 61 | 73 | -- |
| shiplengths | 5.56 | 5.92 | 6.73 | 6.97 | 6.96 | 7.08 | 8.47 | -- |

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